Summary Report, Breakout Introduction

and Breakout Groups

for the

DOE National Bioenergy Center

Strategic Partnerships Workshop

April 11 - 12, 2001

Colorado

DRAFT

Strategic Partnerships Workshop
April 11-12, 2001

Summary Report

Bioenergy and Biobased Products

Hosted by the DOE National Bioenergy Center

Helena Chum, NREL and Lynn Wright, ORNL, Co-Chairs
Merwin Brown, NREL, Overall facilitation

April 27, 2001

Meeting of Combined Federal Laboratory Capabilities

- 95 attendees:
  - 31% USDA ARS, FS, OEPNU (representatives from 17 labs and sites)
  - 5% EPA (DC and lab representative) and invited guests (Hon. Mark Udall, CO)
  - 64% DOE - DC program, field and regional structure, and 10 of its labs (including 20% involved with the technical workshop organization from NREL and ORNL)
- Workshop format
  - Background book of DOE and USDA FY01 R&D program presentations, Biomass R&D Board Strategic Plan (see http://www.bioproducts-bioenergy.gov), and related materials from EPA were distributed ahead of time -- 180 pages covering
    - DOE's biopower, biofuels, agriculture and forest products, and energy biosciences: $141 million
    - USDA's in-house programs on biobased products/ bioenergy and grant programs: $91 million (an additional $150 million facilitates commodity grain use for expanded biofuels production)
  - Round table panel with program managers/leaders
  - Laboratory capabilities presentations (USDA/ARS, FS; DOE and EPA)
  - Inventory of FY98 federal programs and examples of ongoing partnerships
  - Breakout sessions on
    - Identify near term gaps in current programs and partnership opportunities
    - Identify key scientific and technological challenges and partnership opportunities

2

DOE National Bioenergy Center's Strategic Partnerships Workshop April 12 breakout session participants

3

R&D Gaps and Needs Identified

- Biomass Systems Integration
- Biomass Systems Analyses
- Technology
  - Feedstocks R&D
  - Conversion R&D
  - Products R&D
- Social Research

Some GAPS in existing programs

(based on background presentations & participants' knowledge)

- Science
- Facilitating Market Development
- Education and Outreach
- Partnerships/Technology Transfer

Some NEEDS identified

(program areas were not fully reviewed)

4

Biomass Systems Integration Gaps

- Integration of residue collection and plant production with conversion to products and energy
  - Demonstration and systems research including technical, economic, environmental, and ecological performance data over time to provide/validate life cycle data estimates.
- Infrastructure gap in the feedstock supply chain involving harvesting (or residue collection), transportation, densification, sorting, merchandizing
  - Cost reduction of delivered feedstock to processing plant site. Develop and validate models and tools for estimating feedstock cost delivery at various distances.
- Use and develop computational tools to better understand biomass systems

5

Biomass Systems Analyses Gaps

- **Evaluate product performance, life cycle analysis, and environmental footprint compared to competing products.**
  - Technical and and economic analyses of all cycle elements
  - Life cycle and environmental footprint analyses of all inputs and outputs
  - Benefits to energy supply increase, security, and diversity; economic development (including to farmers); quality of life and sustainability
- **Develop tools to understand biobased products and bioenergy market dynamics and identify drivers leading to market penetration scenarios**
  - Market dynamics and competition with existing production systems
  - Product/energy market penetration
- **Understand biobased products and bioenergy linkages at global, regional and local scales with respect to environmental and ecological impacts.**
  - Understand carbon, nitrogen, and key nutrient cycles
- **Update tools and databases for federal partners working with industry in the selection of the federal R&D product portfolio.**

6

Technology Gaps - Feedstocks

- Establish and maintain a broad access feedstock availability and properties database
- Identify target markets and develop well-defined and public plans for use of genetically modified organisms
- Understand and control feedstock properties and conversion technology needs
  - moisture
  - density - cost effective densification
  - composition and change with storage conditions.....

7

Technology Conversion R&D Gaps

- Process monitoring and control
- Technologies that benefit multiple pathways
- New composition analysis tools (fast, inexpensive, rugged)
- Data base on industrial enzyme systems -- structure and function
- Accelerate development of small scale biopower units that use agriculture and forestry residues

Significant progress made to date but...

- **Missing fundamental understanding still hinders technological progress**
- **Breakthroughs needed in many areas**

8

Technology Gaps - Products

- **Develop new cost-effective products using inherent biomass properties and design biomass for products**
- **Models and databases for identification of product opportunities (includes economics and life cycle) with industry**
- **Other fuels**
  - Increase emphasis on other oxygenates in addition to ethanol
- **New and expanded bioproducts (many classes possible)**
  - Organic pesticides, bioremediation products
  - Non-woven products, activated carbon uses
  - Fertilizers and additives (soil amendments)
  - Syngas as chemical intermediate
  - Pharmaceuticals and nutraceuticals
  - Lubricants, epoxies, coatings, adhesives, etc.
  - Building products with improved durability and performance
  - Explore aquatic plants as source of targeted bioproducts
- **Molecular modeling of biomass and components**

Integrated research from plant science to products critical

9

Social Research Gaps

- Understanding the social value and perception related to bioenergy and biobased products
- Understanding effects of new products may have on displacing markets for existing agriculture and forestry products

10

Science Needs

What is needed to accelerate progress in bio areas?

- **Enhanced knowledge of fundamental plant physiology, of cellular biology, of cellular enzymes and their functions, and of the controlling mechanisms in plants**
- **Improved functional properties of biomaterials to meet future needs**
- **Maintaining high-value uses of biopolymers, lipids, extractives, etc.**
- **Analytic tools to identify viable opportunities for both commercial and societal impacts**
- **Ability to employ flexible chemical, thermochemical, & biological processes**
- **Tools to shorten cycle time for developing new commodity crops and strains**
- **Novel approaches to separation and pretreatment**
- **Life cycle analyses of both ecosystems and processes**

Science frontiers to watch

- **Molecular biology**
- **Information technologies**
- **Molecular design – chemical and biological**
- **Nanosciences**
- **Chemical sciences**
- ***In silico* Biology**
- **Computational modeling**
- **Robotics and automation to improve crop production, harvesting, molecular biology, genetic screening, combinatorial screening, etc.**
- **Sciences of complex systems (biology/industry)**

11

Facilitating Market Development - Needs

- Standards and labels
  - Bioproducts substituting petrochemicals are forced to use inappropriate standards (e.g., petroleum lubricants, ash from coal versus biomass and coal ash) - currently a barrier
  - New products may require new standards and labels to indicate environmental benefits - definitions and life cycle analysis will be needed - lack of standards/labels is a barrier
- Verification/certification of product performance
  - Independently verified performance of technologies and products can accelerate permitting and marketing.
    - EPA's Environmental Technology Verification Program could facilitate commercialization of small biopower systems
- Government purchases can reduce barriers to commercialization

12

Education and Outreach Needs

- Targeted public education and outreach
- Continue education and outreach within agencies and across agencies on biobased products and bioenergy
- Increase coordination across agencies
- K-12 education
- Multidisciplinary undergraduate and graduate education including biomass systems (continuity essential)

13

Partnerships Work Well When

- Each partner's contribution is recognized, valued, and documented in presentations and publications
- Coordinated planning occurs annually or more frequently
- Ideas, results, and problems are discussed frequently by phone and e-mail
- Papers and reports are co-authored by staff from all partner groups and are encouraged by management
- $$ greatly helps -- joint proposals, subcontract/IAG with in-kind cost-share work. Jointly defined work without exchange of $$ also works
- TRUST - e.g. graduate school pals often collaborate though at different institutions

More than 50 partnerships were highlighted by the participants in a one hour brainstorming session highlighting these positive features.

14

Examples of Partnerships Proposed at the Meeting

- DOE & FS project using forest thinnings to power a small modular system
- NREL & ARS collaborating to share corn germplasm and analytical capabilities
- USDA & EPA working together to develop and test bioproducts with superior properties to replace petrochemicals
- ARS and NREL collaborating on developing micro-organisms for pretreatment and enzymes
- ORNL and ARS collaborating on separations using unique membranes
- Increase involvement of EPA with USDA and DOE in Life Cycle Analysis
- Integrate FPL and DOE efforts on advanced housing; use of renewables in construction, advances in energy efficient techniques
- Greater use of USDA repositories for microbes and plants by DOE programs
- Greater collaboration between USDA, EPA and DOE on biodiesel development and testing
- Formal dialogue between National Forest managers, Research foresters, and DOE on bioenergy and forest management
- Regular meetings between USDA ARS and FS laboratories
- Joint project reviews by DOE/USDA

Many ideas for improving management of partnerships across and within laboratories

15

Future Steps

- **Draft Presentation Report Distributed to All Participants for Comments on 4/27/01**
- **Report from Workshop - June**
  - Workshop report and Appendices:
    - Background material - electronic (already distributed as hard copy)
    - Presentations at meeting - electronic
    - Agenda and Participants
- **Capabilities Statements Architecture - June**
  - Review by participants
  - Web posting at http://www.bioproducts-bioenergy.gov/
- **Questionnaire - May**
  - Follow up meetings -- more detailed technical? Same level? Where?
- **5th Biomass Conference of the Americas - September**
  - Session with academia and industry- at Orlando, Florida, 9/20-21/01 http://alpha.fsec.ucf.edu/bioam/

16

Breakout Introduction

Strategic Partnerships Workshop

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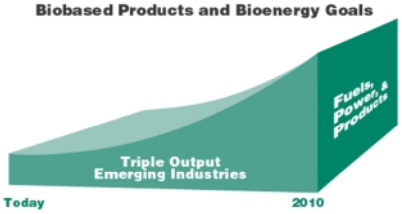
April 11-12, 2001
Lakewood, Colorado

17

Biobased Products and Bioenergy Goals



Current baseline for emerging industries:
- ethanol, 1.5 billion gallons
- biodiesel, 6 million gallons
- electricity, 60 billion kWh (from 10 thousand megawatts of capacity)
- emerging products, 10-15 billion pounds (5 - 7.5 million tons).

Figure 1. Biobased Products and Bioenergy Goals: Consistent with federal resource conservation and environmental policies, triple output of emerging industries in fuels, power, and products and facilitate an increase in efficiency of use in mature industries, with special attention to application of new and emerging technologies. (Note: triple refers to specific fuels, power, and products output or any combination)

18

Strategic Plan Examples of 2010 Technology Development Milestones

- Halve the year 2000 cost of producing sugars from lignocellulosics
- Develop technologies for cost-competitive biomass gasification platforms for both power and biorefinery coproducts
- Develop 250 new biobased products for commercialization. This number includes at least 20 high-energy use impact products

19

Strategic Plan Examples of 2002 Technology Development Milestones

- **Demonstrate integrated commercial scale facility for multiple products**
- **Review environmental and ecosystem monitoring**
  - federal, state, and local governments forestry, agriculture, and environmental agencies and private sector and non-government organizations
- **Develop tools and information resources**
  - facilitate identification of biobased products and bioenergy technologies that provide economic, agricultural, energy and environmental benefits simultaneously
  - produce a plan to accelerate their development…
- **Complete inventory of public resources and facilities**

20

Strategic Plan Goal 7. Facilitate tripling of emerging biobased products and bioenergy

Consistent with federal resource conservation and environmental policies

- Cofiring in 5% pulverized coal boilers by 2005?
- Triple biofuels production by 2010.
- 250 new biobased products…20 high energy impact by 2010.

GAPS

- Are there near term pathways not explored? (examples of technologies)
- Resources not explored (animal residues, crop residues, other?)
- Program linkages that should be strengthened? (environment, ecological data?)

PORTFOLIO

- Is the overall government program robust to reach this goal?
- Is the overall government program robust to develop the science and technology for the future?

21

Strategic Plan Goal 4: Foster innovation-driven science of biomass feedstocks, biobased products, and bioenergy and quickly incorporate these scientific results in the relevant technology development activities (Second day discussion)

- Evaluate the federal, state and private sector biobased products R&D portfolio to identify gaps in frontier science and technology (every two years)
- Identify R&D issues that would greatly benefit from dedicated Centers of Excellence attention and, where appropriate, extend existing or develop new program that address key challenge areas

22

Desired Outcomes for the First Breakout

GAPS

- Are there near term pathways not explored? (examples of technologies and products' categories)
- Resources not explored (animal residues, crop residues, other?)
- Program linkages that should be strengthened? (environment, ecological data?)

PORTFOLIO

- Is the overall government program robust to reach the tripling goal?
- Is the overall government program robust to develop the science and technology for the future?

23

Desired Second Breakout Outcomes

- Identify key scientific and technological challenges
- Idenfity key options for partnering
- How to accelerate the time for technology development with incorporation of basic science developments and breakthroughs?
- How to identify scientific frontiers that will impact this area?

24

Breakout Session Reports
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Hosted by the DOE National Bioenergy Center
Helena Chum, NREL and Lynn Wright, ORNL, Co-Chairs
Gene Petersen & Joe Bozell, NREL and Brian Davidson, ORNL, Posters/Capabilities Input Co-Chairs
Merwin Brown, NREL, Overall facilitation

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Breakout Group 1

Near Term Gaps and Partnerships
Steve Kelley, NREL Facilitator
Janet Cushman, ORNL Scribe
Susan LeVan-Green, FPL Rapporteur

Key Challenges - Prioritized

- Infrastructure issues - cost of collection, harvesting, and transportation
- Analyses
  - evaluate energy, fuels, markets, products impacts versus competing products
- Feedstock R&D
- Social issues
  - use of genetically modified organisms (GMO), understanding of environmental and ecological issues and public perception
- Partnerships and Technology Transfer
- Conversion Research

Infrastructure Issues - Priorities

- Feedstock supply infrastructure - harvest, collection, transportation - to reduce costs
- Training of new professionals with diverse backgrounds.

Other issues identified:
- Understand implications of rapid increase in ethanol production
- Infrastructure to support bioenergy development
- Agricultural and wood fiber sorting/merchandizing center

Analyses Issues - Priorities

- Impact of use of biomass versus traditional products
  - Evaluate product performance, life cycle, environmental footprint
  - Economic and market dynamics
    - Systematic overview of implications
  - Linkages with global climate change

Other topics identified:
- Biorefinery life cycle tools
- Economic analysis of new products and technologies

Feedstocks - priority issues

- Data base of feedstock properties broadly accessible
- GMO test and evaluation of safety
- Address public perception and set public policy to minimize concerns

Other issues identified:
- Understand landowner decision making process
- Densification of biomass
- Marine feedstocks
- Hazard communications for animal residues

Social Issues - Priorities

- Understanding of social values and public perception related to bioenergy and bioproducts
- Public education and outreach
  - Advantages of biomass, bioenergy, and biobased products versus fossil fuel equivalent products

31 Group 1

Partnerships and Technology Transfer Issues - priorities

- Support small businesses - most willing to take high risks
  - new technology commercialization - reduce technical risk (innovative grants)
  - support commercialization risk reduction - e.g., revolving loans and other methods
- Monitor and understand international R&D
- Understand private industry R&D
- Understand and modify key regulations to accelerate new technology implementation

32 Group 1

Conversion Issues

- Process monitoring and control
- Technologies dealing with multiple feedstocks
- New compositional analysis tools

Other topics identified:
- Accelerate small scale biopower units development that use ag and forest residues
- Alternative fuels other than ethanol
- Process intensification (multiple unit operations in one)
- Use municipal solid waste and animal residue
- Understand waste generation from bioenergy facilities
- High throughput anaerobic digestion systems

33 Group 1

Policy Issues registered

- Risk sharing and investment buy down
- Domestic and international marketing
- Landowners decisions
- Policies of residue collection and use
- Non-market tools (such as credits for green products/energy)
- Duration of policy commitment
- Incentives for large and small companies

34

Examples of Outstanding Partnerships

- Housing with FPL, HUD, FEMA, National Association of Home Builders
  - new more energy efficient & durable homes
  - in-kind support
  - educational vehicle for builders and training tool
- ARS - Peoria - oil encapsulation technologies
  - Licensing of intellectual properties to “Fantesk” for a variety of companies in specific fields of use

35 Group 1

Examples of Outstanding Partnerships - cont

- PNNL - Industry CRADA (funds in)
  - Industry need addressed by lab to successful implementation
- Researcher-to-Researcher partnerships
  (usually based on prior common educational experience)
  - NREL and SRS - applications of Near IR to solid wood properties prediction
  - ORNL and SRS - wood chips storage
  - ORNL and industry - dues paying cooperative for short rotation wood research
- Partnerships resulted from OIT calls
  - IPST and LBNL - lab had laser technology used for on line evaluation of paper properties
- ARS West/Industry to help move product to market - lot of recognition

36 Group 1

Breakout Group 2

Science and Technology Challenges and Partnerships

Robin Graham, ORNL Facilitator

Joe Bozell, NREL, Scribe

Tom Jeffries, FPL, Rapporteur

Technological challenges

- Techno-economics to guide selection
- Transportation
- Innovative pretreatments/separation
- Cutting out process steps (process intensification or consolidated processing)
- Maintain and maximize value (cascade of uses)
- Push the limits of plant and microbial systems
- Commodity products besides energy or ethanol

Technological challenges (cont)

- Rapidly identify and propagate desirable traits in trees
- Identify and develop a gymnosperm model for genetic studies
- Improve genomic information
- Much better knowledge of how to manipulate plant genetics, physiology and biochemistry and integrate this knowledge with informatics

Techno-Economics to Guide Selection

- Identify natural drivers and barriers
- Better grasp of actual costs
- Better use of economic tools
- Improve industry/partnerships and better handling of intellectual property
- Better market analysis from micro and macro perspectives

Transportation

- Microscale processing
- Concentration at the farm or local level
- Low cost ways of pelletizing or baling

Innovative pretreatments and separation

- Need innovative pretreatments (breakthroughs)
- Cut out as many processing steps as possible (process intensification or consolidated processing)
- Produce high value products
- Integrate upstream and downstream processing
- Tailor feedstocks (plants) to conversion process system

Commodity products in addition to energy or ethanol

- Think in terms of function rather than materials
- Identify new products; don't copy existing products
- Try to use or engineer highest value in the feedstock

Supplement/complement petroleum-derived products based on inherent biomass properties

43 Group 2

Pushing the limits of plant or microbial systems

- What would happen if we get rid of or modify lignin? Cellulose? Hemicellulose? Etc…
- How far can we push the compositional elements?
- How can we modify the gross properties of wood
  - Strength, branching, extractives
- Engineer plants for increased lipid production
  - Producing the products themselves
  - Lipids, plastics, enzymes in cell walls

44 Group 2

Accelerating technology development and implementation

- Test or demonstration farms with regional processing centers
- Interagency field stations
- Make use of county agent and forest contacts

45 Group 2

Identifying Scientific frontiers

- Computational biology to build on existing trends
  - Genomics
  - Proteomics
  - Structural biology
  - Better understanding of complex systems
  - Metabolic engineering of biochemical and regulatory pathways
  - Develop specific tools for renewable biomaterials and bioenergy
  - Integrating biomass supply with ecological and economic models
- Merging nanotechnologies with biological systems
- Robotics and automated systems in cropping and processing systems

46 Group 2

Partnerships

- Regular meetings between USDA ARS and FS laboratories
  - To facilitate coordination of activities
  - Make better use of facilities
  - Address overlapping areas in biomass utilization, supply
- DOE assist in USDA project reviews and vice versa
- Joint solicitations that require joint collaboration
  - Need to work out details for funding appropriation
- CRADA provisions that are more amenable to partnerships

47 Group 2

Partnerships (2)

- Improve formal partnerships between National Forest System/State and regional with US DOE for large scale utilization of overstocked stands
- Formal dialog on bioenergy, bioproducts and forest management
- Advanced housing partnership
  - Involve FPL/FS materials development with US DOE energy efficient housing efforts
- Employ professional societies for developing partnerships

48 Group 2

Partnerships (3)

- Share templates for successful collaboration
- Promote regional collaborations for regional products
- Links with land grant universities to increase students and academics collaborating with ARS and DOE laboratories
- Encourage the use of USDA repositories for plant and microbial collections

Needs

- Multidisciplinary teams
- Understand demand/supply -- “Don’t try to push a rope”
- Total life cycle analysis for assessment and analysis to avoid unintended consequences of implementation of specific pathways
- Broad education for careers in renewables, biotechnology, biology, chemistry, chemical engineering, and foster systems approaches and integration.

Breakout Group 3

Near-Term Gaps and Partnerships
Marilyn Brown, ORNL, Facilitator
David Johnson, NREL, Scribe
Carol Purvis, EPA, Rapporteur

Overall Major Challenges

- Biomass Systems Integration
  - Production of feedstock or use of residue,
  - Conversion system to product/energy
  - Integration with use
- Biomass Systems Analyses
  - Life Cycle
  - Economics
  - Environmental/Ecological
- Certification/Verification/Market Enablers

Current Gaps

- Technical Systems Integration
  - Residue and its use
  - Demonstrations still needed in selected area
  - Biomass handling - there are still issues
- Market Development/Commercialization
- Life Cycle Analyses
- Optimization of feedstock/product
- Systems Analyses
  - interaction between bioproducts and commodities as they affect feedstock economics, both supply and secondary effects on employment and processing

Technical System Integration

- Beginning to end (more than cradle to grave -- the cradle has to be built)
  - Plant science to production and harvesting
  - Conversion to product/energy
  - Use of product/energy
- Possible areas
  - Performance testing
  - Standards
  - Market integration
  - Life cycle analysis
    - Include non-market benefits and inter-commodity effects
  - Feedstock optimization (cascade of uses)

Residue Utilization

- Crops
  - Market value
  - Availability (surveys?)
  - "Mental Infrastructure" - initially used to describe farmers who need to be part of the effort
  - Large scale trials needed
- Animal Biosolids (new title for animal wastes)
  - Environmental problem and big opportunity
- Forest
  - Fire management plan
  - Excess biomass produced than used
  - Timber stand improvement
  - Brush removal and use
  - Logging residues for multiple products
- Municipal Solid Waste (?)

Small Biopower Plants for Residue Use

- Technology - gasification/gas cleaning/ engines or turbines
- Ongoing activities need
  - Coordination
  - Acceleration
  - Systems integration
    - biomass handling/interconnection
  - Economic/system/life cycle analysis
  - Verification/certification procedures (a possible role for EPA's Environmental Technology Verification Program)

Bioproducts - some gaps

- Oxygenates
- Mustard pesticides
- Epoxies, paints, adhesives, coatings
- Lubricants (such as from soy and cotton seed)
- Bioremediation products
- Activated carbons and alternative fibers
- Syn gas derived chemicals
- Alternative building materials
- Pharmaceuticals

Bioproducts - cont

- Criteria for ranking
  - In production by 2006-2008 to impact 2010
  - fossil fuel saving
  - impact on farm income, forestry income, and rural development
  - environmental impacts
  - relative need for more research and development work
  - industry participation in development

Other Gaps

- Other fuels and products
  - FT fuels, DME, DMM, oxygenates
  - Integration among programs (H2, MSW, etc)
  - Mixed alcohols, …
- R&D to support market development
- Small scale processes
  - power, fuels, waste utilization, products
- Biomass handling
- Interconnects
- Certification/verification processes
- Regulations

Partnering Opportunities

- Life Cycle Analysis
  - DOE, EPA, USDA, NIST, impacted industries
  - Current corn stover to ethanol - phase II
    - Need EPA involvement
  - Bioproducts require LCA
- Greening of the government/Executive Order 13101
  - Full government partnership
  - Lead by example:
    - ARS- Beltsville use of biodiesel
    - Use of biolubricants/biocleaners

Partnering Opportunities

- Environmental labeling, regulations, specifications
  - Require LCA information
  - Possible review of EPA Construction Guidelines for biobased products and bioenergy impacts
- Coordination of feedstock production, harvesting, and conversion
  - Need common language; set of parameters and measurements
- Education and Outreach
  - USDA, DOE, EPA, and others
- Incentives and Stimuli

Breakout Group 4

Key Scientific/Technological Challenges and Partnerships

Bob Evans, NREL, Facilitator

Lynn Kszos, ORNL, Scribe

Bill Apel, INEEL, Rapporteur

Key scientific and technological challenges

- Plant Science
  - Genetic engineering of cell wall
  - Bioinformatics/plant genome database mining
- Crop and tree production
  - Forest sustainability
  - Crop/soil productivity
  - Phytoremediation
- Durability and performance of biomaterials
  - Characterization
  - Reduce degradation

Key scientific and technological challenges

- Environmental
  - Carbon sequestration
    - Durable goods and products (i.e. engineered soils)
  - Water resource synergies
- Supply engineering (harvest, collection, transport)
- Designer plants (similar to microorganisms)
  - Accelerate breeding feedstocks with specific properties such as nutraceutical value, specific chemical function (crop breeding today takes 10 years…)
- The new biorefinery
  - Flexible thermochemical processing
  - Optimization for maximum value
  - Use of small diameter trees
- Separations technologies (new and improved)

Current Partnering Examples

- Bioenergy feedstocks
- Capture methane from manure for turbine
- Microorganism development for ethanol
- Life cycle analysis of corn stover to ethanol
- Allocation of above and belowground biomass
- Terrestrial carbon sequestration
- Cellulase genetics
- Fiber and protein from manure

Current Partnering Examples

- Soil carbon characterization
- New uses for corn and soybeans
- Health benefits analysis of cofiring (emission profile)
- Cofiring of willow and switchgrass
- Regulatory flexibility for cofiring

Fostering Collaboration

- Cross group communication
  - This meeting!!!!!
  - Forest thinnings for modular systems: DOE/FS
  - Assess corn stover composition: NREL/ARS
  - Fiber properties and characterization: NREL/Forest Products
  - Conversion with microorganisms: NREL/USDA

Fostering Collaboration

- Integrated Strategic Planning
  - Anticipate societal needs before it becomes a problem. e.g., green chemicals.
  - Integrated LCA for systems with multi-agency collaborations

Scientific Frontiers

- Designer Plants (genomic/expression/proteomics)
- Separation Science (A-Z in the process)
- LCA
- Physical manipulation of feedstock to improve quality (e.g. densification, etc.)